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July 31, 2006

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It is respectfully requested that this application be given the benefit of the foreign filing date under the provisions of 35 U.S.C. §119 of the following, a certified copy of which is submitted herewith:

Application No.	Country of Origin	Filed
0225522.2	GREAT BRITAIN	1 November 2002

Respectfully submitted,

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F ovation

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1. Your reference — 003-1041

2. Patent application number *(The Patent Office will fill in this part)* — 0225522.2

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

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   Patents ADP number *(if you know it)* — 8478588001

   If the applicant is a corporate body, give the country/state of its incorporation — UNITED KINGDOM

4. Title of the invention — OPTICAL COMPONENT ASSEMBLY

5. Name of your agent *(if you have one)* — ERICA LINDLEY GRAHAM DUTTON

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   Patents ADP number *(if you know it)* — 8478596001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
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11. I/We request the grant of a patent on the basis of this application.

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Date 1st November 2002

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01494 778139

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OPTICAL COMPONENT ASSEMBLY

The present invention relates to mounted optical components and finds particular application where two or more optical components are mounted for optical alignment.

Flip chip mounting is known for use in mounting semiconductor devices. It is also known for use in mounting optical devices. The technique comprises fabricating a planar device and then inverting it onto a bonding area on a substrate. Bonding material applied to the bonding area can also be used to make an electrical connection to the device and this has advantages in some circumstances over the older technique of wire bonding. For example, for high speed devices it has been found that wire bonds can act as an unwanted aerial.

According to a first aspect of the present invention, there is provided an optical assembly comprising:

i) at least first and second optical components, each having a bonding surface and an optical confinement region; and

ii) a shared substrate,

the first and second components being mounted on the shared substrate by means of their bonding surfaces such that their respective optical confinement regions are optically coupled in use,

wherein the distance from the bonding surface to the optical confinement region for the first component is matched to the distance from the bonding surface to the optical confinement region for the second component to achieve said optical coupling in use.

Such an assembly can be constructed using flip chip mounting for the first and second components to achieve the optical alignment in a relatively simple manner. Because the distances from the bonding surfaces to the confinement regions for the first and second components are matched, flip chip mounting produces passive alignment in the direction normal to the bonding surfaces. Alignment in the other two directions, in a plane parallel to the bonding surfaces, can be achieved using known alignment marking techniques.

In general, the distances from the bonding surfaces to the confinement regions for the first and second components can be matched using more than one different technique. For example, the distances can be matched by fabricating both components to give accurately controlled distances. Alternatively, they can be matched by adjusting the distance for one of the components so as to match the distance for the other component.

The last mentioned technique has the advantage that it could be used where the first and second components have been fabricated, or even sourced, separately. It is possible to add a layer of material to the first or second component in order to match the distance between its confinement region and its bonding surface to that of the other component so that subsequent flip chip mounting will produce the required passive optical alignment.

In practice, it is not always necessary in an embodiment of the present invention that the distance between the optical confinement region and the bonding surface in a first component is exactly the same as that distance in a second component. Firstly, the accuracy required for optical alignment will vary. For example, if optical loss is a very significant factor, or if a component has a very small beam spot size, it is likely that a high degree of accuracy in optical alignment between the components will be necessary. If losses are not important, for example because the local optical power budget is high, or beam spot size in the components is high, then the accuracy required may be lower. Using planar fabrication techniques for the first and second components, it should be possible to achieve an accuracy in the distance between a bonding surface and an optical confinement region which is in the range 300 nm or less, or even 100 nm or less. Secondly, in order to get optical alignment it may be necessary to take the mounting technique into account. For example, the use of bonding material introduces the thickness of the layer of bonding material itself which has to be taken into account. If different bonding techniques or materials are used for the first and second components, then the thicknesses of the layers of bonding material may be different.

Planar fabrication techniques which might be used include chemical vapour and physical evaporation deposition techniques. These are both capable of high degrees of accuracy in control of layer depths. However, they have disadvantages. They tend to be expensive techniques to use and if used for thick films, for instance 1 μm or more,

temperatures are made possible by using thermal- or photoinitiators resulting in polymerization of the organic matrix. The polymerisation may be achieved through organic carbon-carbon double bond openings and crosslinking. Known thermal initiators include benzophenone and various peroxides, such as benzoylperoxide and layroyl peroxide. Known photoinitiators include phenyl bis(2,4,6-trimethylbenzoyl)phosphine oxide (Irgacure 819) and 1-hydroxy-cyclohexyl-phenyl-ketone (Irgacure 814). .(Irgacure initiators are products of Ciba Specialty Chemicals Inc. and "Irgacure" is a registered trade mark.)

Simple processing techniques:

For example, a hybrid glass material can be designed to support lithographic processing by including an organic component which polymerises by cross-linking. This might be for example one or more of the functional hydrocarbon compounds comprising acrylates, epoxides, alkyls, alkenes, or aromatic groups which support photopolymerisation. Gray scale lithography of hybrid glass materials is described for example in the following: "Fabrication of Micro-Optical Structures by Applying Negative-Tone Hybrid Glass Materials and Greyscale Lithography", by A.H.O. Kärkkäinen, J.T. Rantala, M.R.Descour, published in Electronics Letters, Vol. 38, No. 1, pp 23-24 (2002). Further, hybrid glass materials can be processed to produce a thick assembly structure (for instance in the range from 1 micron to 1 mm) by lithographic means.

Adjustable mechanical properties:

In general, the mechanical properties of a hybrid glass can be adjusted by changing the relative content of inorganic versus organic materials. For example, if the concentration of <u>inorganic</u> materials is increased:

- the coefficient of thermal expansion (CTE) decreases
- the hardness increases
- the stress modulus increases
- stability typically increases.

If the concentration of <u>organic</u> materials is increased:

- the material softens and becomes more elastic
- the CTE increases
- stability typically decreases.

As well as the above general mechanical characteristics, determined by the relative proportions of inorganic/organic materials, the behaviour of a hybrid glass can also be affected by the specific components selected. For example, some organic materials will withstand higher processing temperatures than others. The use of thermal- and/or photoinitiators can affect thermal stability and an inorganic matrix may capture and protect an organic matrix and thereby give higher stability.

As well as the reference given above, hybrid glasses are also disclosed in the following publication: "Siloxane-Based Hybrid Glass Materials for Binary and Grayscale Mask Photoimaging", by A.H.O. Kärkkäinen, J.T. Rantala, A. Maaninen, G.E. Jabbour and M.R. Descour, published in Advanced Materials, Vol. 14, No. 7, pp 535-540 (2002).

An embodiment of the present invention in its first aspect might comprise an optical assembly as described above, wherein at least one of the first and second optical components includes a layer of material between its bonding surface and its optical confinement region which layer comprises a glass material having both organic and inorganic components.

The layer might provide the whole distance between the bonding surface and the optical confinement region, or only part thereof.

As indicated above, flip chip mounting can be used to mount two or more optical components, each having its own respective substrate, in passive optical alignment on a shared substrate. A flip chip mounting process in which each component has been fabricated on its own substrate and is then inverted onto the shared substrate and mounted via its bonding surface, creates a sandwichlike optical assembly in which the optical components are positioned between the shared substrate and their own respective substrates.

Hence according to a second aspect of the present invention, there is provided an optical assembly comprising at least first and second optical components mounted in optical alignment with each other, each component comprising at least one layer and a substrate and providing an optical confinement region in use, wherein the optical assembly further comprises a shared substrate, the first and second optical components each being

mounted so that its optical confinement region lies between its respective substrate and the shared substrate.

In embodiments according to the invention, a substrate comprised by a first component might have different characteristics from a substrate comprised by a second component, and in particular might have a different depth. When first and second components have been inverted onto a shared substrate, their own respective substrates need have no effect on optical alignment which is determined instead by the relationship between each component's bonding surface and an optical confinement region in the component. This might be particularly convenient for example where one of the components comprises an active device such as a laser diode which requires heat sinking. A heat sink can be provided as, or in contact with, the respective substrate of the active device without affecting its optical alignment with another component once mounted on the shared substrate.

According to a third aspect of the present invention, there is provided a method of mounting at least two optical components in optical alignment on a shared substrate, the method comprising the steps of:

i) using a planar fabrication technique to adjust the distance between an optical confinement region and a bonding surface in at least one of the optical components so that said distance is matched for optical alignment in use of the at least two optical components; and

ii) flip chip mounting said at least one of the optical components in said optical alignment on the shared substrate by means of its bonding surface.

In an example of an embodiment of the present invention, a first component might comprise a semiconductor chip such as a laser diode and a second component might comprise a waveguide, particularly a planar waveguide. These can be fabricated separately, indeed they can be sourced separately, and then mounted in optical alignment by flip chip mounting to create an optical assembly according to an embodiment of the present invention. In order to achieve the optical alignment after step ii) above, particularly for components which have been sourced separately, it is likely that step i) will be important to adjust the distance between an optical

confinement region and a bonding surface of one of the components since they are unlikely to have respective substrates of identical or nearly identical thickness.

The combination of a laser diode and a planar waveguide as the first and second components is likely to be a particularly useful one since the waveguide can be used to direct the output of the laser to another component or components, such as an optical fibre or a modulator. Further, the waveguide can act as an external cavity for the laser diode, thus for example narrowing its linewidth.

Packaging, assembly and alignment of optical components and systems can potentially become easier, cheaper and/or more reliable by using an embodiment of the present invention. Embodiments of the present invention are particularly suitable for packaging and integration of optoelectronic components at wafer-level.

An advantage of embodiments of the present invention is an increased flexibility in making electrical connection to optoelectronic components. Not only can wire bonds be used, for instance from a device to contact pads on a substrate, but connection can also or alternatively be made through the mounting by using a conductive material at the mounting interface to the shared substrate, together with contact pads or areas on the shared substrate.

A process for wafer level packaging, and a packaged assembly, will now be described as embodiments of the present invention, by way of example only, with reference to the accompanying figures in which:

Figure 1 shows schematically, in side view, a step in assembling a pair of optical components in optical alignment on a shared substrate;

Figure 2 shows the optical components of Figure 1 assembled on the substrate;

Figure 3 shows schematically in transverse cross section the structure of a laser diode which might be used as a first of the optical components of Figure 1;

Figure 4 shows schematically in transverse cross section the structure of a waveguiding device which might be used as a second of the optical components of Figure 1;

Figures 5 and 6 show schematically in longitudinal cross section an arrangement for providing electrical contact to a laser diode as one of the optical components shown in Figure 1;

layers might be deposited in any of a variety of known ways such as spin-on, solution dipping or evaporation techniques. It is relatively easy using known deposition techniques to control the depths of deposited layers which are several micrometers thick, for instance more than 15 micrometers thick, to within an error margin of 300 nm, or even 100 nm, or less.

Optical alignment

In Figures 1 and 2, relatively simple core and cladding layers 115, 140, 120, 125, 105, 145 are shown. In practice, the layers may have an even simpler, or a more complex, structure. For example, the cladding layers 120, 105 might themselves be multi-layered.

In a waveguiding device 135, there may be fewer layers involved. This might be the case if the substrate 150 exhibits optical quality and its refractive index is lower than the index of the core layer 140. In these circumstances, the lower cladding layer 145 might not be required. Alternatively, in a laser diode 130, the layers may have a complex structure in order to provide current blocking either side of a gain region in order to achieve lasing.

Referring to Figures 3 and 4, regardless of the layer structure the aim of optical alignment by flip chip mounting will usually be to align optical confinement regions in the optical components. If the relevant optical confinement regions are aligned then optical radiation propagating in a first device can generally be coupled to propagate in a second device. Further, it will often be the case that each optical confinement region has a propagation axis and the aim of the optical alignment is to align these axes. Alternatively or additionally, the aim of the optical alignment might be to achieve maximum overlap between beam spots for radiation travelling in the devices.

Importantly, it is not necessarily just the dimensions of the upper cladding layers 120, 105 which are important. The axis along which radiation travels in use of a device will usually be determined by several factors which control the position and shape of an optical beam travelling along a confinement region. These factors will include for example the thicknesses of all relevant core and cladding layers and their relative

refractive indexes. These factors together will control the beam spot size and cross section in use.

Figure 3 shows a schematic cross section of the layer structure of a laser diode 130 in a direction transverse to the optical axis in use. Referring to Figure 3, a form of laser diode 130 which might be used has a buried active region 330. In more detail, the laser diode 130 has an "n"-doped layer 325 with a raised mesa structure supporting an active region 330. Above the active region 330 there is a "p"-doped layer 315. To either side of the mesa structure there are insulating regions 320. In use, current is passed across the pn junction generated by the proximity of the "p"-doped layer 315 to the "n"-doped layer 325 in the mesa structure. The insulating regions 320 block the passage of current to either side of the mesa structure. The result is that the current is channelled through the active region 330 to produce maximised lasing activity.

The layers of a laser diode 130 have two functions. A first function may be an electrical function as described above which encourages lasing to occur and to generate optical radiation in the laser diode 130. The second function is the optical function of providing a confinement region 300 in which the optical radiation so generated will propagate. This is done by selecting layers having appropriate refractive indexes. The confinement region 300 in the laser diode 130 shown in Figure 3 has a central propagation axis 335 in use.

Figure 4 shows a schematic cross section of the layer structure of a waveguiding device 135 in a direction transverse to the optical axis in use. A form of waveguiding device 135 which might be used has a buried ridge 430 of core material. The ridge 430 is buried in an upper cladding layer 415 and sits on a lower cladding layer 420. This structure produces a confinement region 400 centred on an axis 435 in the core material 430.

Referring to Figures 5, 6 and 7, in this embodiment a function of the waveguide device 135 is to provide feedback to the laser diode 130 and it is provided with a DBR grating 520 for this purpose. The DBR grating 520 is disposed along a surface of the ridge 430.

What is important when the structures of Figures 3 and 4 are flip chip mounted on a shared substrate will usually be that the optical axes 335, 435 are aligned to give sufficient optical coupling in use.

During bump bonding, lateral optical alignment of the laser diode 130 with the waveguide 135 (in a plane parallel to the bonding surfaces 155, 160) is taken care of using the known technique of alignment markings. Alignment in the direction normal to the bonding surface 155 is passive, being primarily determined by the distance of the confinement regions 300, 400 in the laser diode 130 and the waveguide 135 from their bonding surfaces 155, 160. However, the thickness of the bonding material may also be relevant. It would also be possible to use a different mounting technique for one of the components, or to use different bonding materials or thicknesses of bonding material.

In an example in which a laser diode 130 is already present on the shared substrate 110, then the next step is to measure the distance of the confinement region 300 of the laser diode 130 from the substrate 110. This will include the thickness of any bonding material. Based on this information, the thickness of the "upper" cladding layer 105 of the waveguide 135 can be calculated to give optimal optical coupling efficiency between the laser diode 130 and the waveguide 135.

It would of course also be possible to mount both the laser diode 130 and the waveguide 135 at the same time, or to bump bond the laser diode 130 when the waveguide 135 is already in place.

It might be noted that it is not essential that more than one component is flip chip mounted. One of the components might be mounted in some other way. The benefit of an embodiment of the present invention can be obtained by using a planar fabrication technique to ensure that a bonding surface of one component is at a measured distance from its optical confinement region so that, when that component is flip chip mounted, it comes into a position for optical coupling with another component.

Electrical Connection

Figures 5 to 7 show schematic cross sections of a laser diode 130 and a waveguiding device 135, in a direction parallel to the optical axis in use, at different stages of

mounting on a shared substrate 110. Referring to Figures 5 to 7, electrical connection can be made to a flip chip mounted device in more than one way. In these figures, the example is used of the laser diode 130 but other components could be selected for electrical connection in any suitable manner.

In Figure 5, the laser diode 130 is shown prior to bump bonding using a thermo-setting bonding material 515. The waveguide 135 is already in place. Electrical connection is provided to the laser diode 130 via a wire bond 500 to a conductive pad 505 on its exposed surface and a further contact pad 510 is provided in the shared substrate 110. Bonding bumps 515 are provided between the laser diode 130 and the shared substrate 110.

Referring to Figure 6, heat has been applied such that the bonding bumps have softened and provided a bond between the shared substrate 110 and the "upper" cladding layer of the laser diode 130 (now inverted). This has brought the laser diode 130 back into optical alignment with the waveguide device 135.

Figure 6 also shows a fibre end 600 supported in a "V" groove 605 in the shared substrate 110 and butt coupled to the waveguide device 135. This type of arrangement is described in European patent application 02256515.4, in the name of the present applicant, the subject matter of which is hereby incorporated.

Figure 7 shows a slightly different arrangement to that of Figures 5 and 6. Instead of a conductive pad 505 on the exposed surface of its substrate 100, a conductive pad 505a has been fabricated onto the opposite face of its substrate 100, prior to creation of the cladding and core layers 125, 115, 120. Electrical connection can be made to this for instance via a side face of the laser diode 130 and/or interconnect material in the substrate 100.

Materials

Referring to Figure 1, known materials can be used in an embodiment of the present invention. For example, any one of the substrates 100, 150, 110 might comprise silicon, glass, composite materials, ceramics including multi-layer ceramics such as alumina, and low temperature-co-fired ceramics (LTTC), and even conventional printed circuit

board materials such as polyimide and FR-4. The core and cladding layers 115, 140, 120, 125, 105, 145 might typically comprise glasses, ceramics, polymeric materials and/or hybrid glass materials which have both organic and inorganic components. After deposition, the upper cladding layer 120, 105 might advantageously be further processed to improve the bonding surface it offers, for instance by polishing such as the known technique of chemical mechanical polishing (CMP).

As mentioned above, a particularly useful class of materials for use here is hybrid glass material, being a material of amorphous structure with both organic and inorganic components. This includes hybrid glasses based on alkoxides used as precursors. It might be noted that some alkoxide groups can remain unreacted and adversely affect optical properties of the hybrid glass produced. Hence in embodiments of the present invention, it is preferable to avoid this situation, for example by using silicon chlorides instead, or chlorides together with alkoxides, or any other suitable technique.

The shared substrate 110 might carry any number of components. Usefully, it might be prepared for instance by pre-fabricating a V-groove to align a fibre to a device that will be mounted on it.

The bonding between the shared substrate 110 and the flip chip mounted components 130, 135 can be based on anodic bonding, thin films of thermo setting glues (such as epoxies or hybrid glass), or the use of a monomeric adhesion and joining layer. Alternatively, a thermo setting top layer can be applied to the components 130, 135 prior to flip chip mounting. For example, a thermo setting upper cladding layer 105 can be used in the waveguide device 135.

Examples of monomeric adhesion promoters are:

1 w-% of glysidoxy propyl trimethoxy silane in isopropanol

1-w % of 3-amino propyl triethoxysilane in isopropanol

1 w-% vinyl trichlorosilane in mesitylene

1-w % of allyl trichlorosilane in mesitylene.

There are known thermo-setting materials for use in mounting optical components, in particular epoxy and silicon based materials, and any one might be used, subject to

performance testing. Possible candidates are for example those manufactured by Epoxy Technology and supplied as Epotek 353ND (non-conductive), Epotek H73 (non-conductive) or Epotek H20E (conductive). Other potential suppliers are: Loctite, Dow Corning and Emerson & Cuming.

Worked Example.

The following describes materials and a method for fabricating a waveguide device 135 of the type shown in Figures 1 and 2 and flip chip mounting it on a substrate 110 in optical alignment with a laser diode 130.

The cladding layers 145, 105 are a composition of 0.1 mol of vinyltrichlorosilane and 0.1 mol of phenyltrichlorosilane. This composition gives a refractive index after final film annealing at 230 degC of 1.5060 at 1552 nm wavelength. The synthesis of the cladding layers 145, 105 is based on hydrolysis and polycondensation reactions. The viscous raw material is diluted into a methylisobutylketone (MIBK) solvent so that the viscosity of the material is 150 mPas. A thermal initiator is added to enhance thermal crosslinking of the vinyl groups. The core layer 140 has the same composition as the cladding layers 145, 105 but is doped with 2% germanium chloride so that its refractive index is 1.5100 at 1552 nm wavelength after final annealing at 235 degC. The viscous core layer material is diluted into MIBK so that the resulting viscosity of the film is around 15 mPas. Thermal and photoinitiators are added to enhance the vinyl crosslinking and make the film photosensitive to UV-light.

Known thermal initiators include benzophenone and various peroxides, such as benzoylperoxide and layroyl peroxide. Known photoinitiators include phenyl bis(2,4,6-trimethylbenzoyl)phosphine oxide (Irgacure 819) and 1-hydroxy-cyclohexyl-phenyl-ketone (Irgacure 814). (Irgacure initiators are products of Ciba Specialty Chemicals Inc. and "Irgacure" is a registered trade mark.)

The following lists the purposes of the precursors mentioned above although it should be noted that they may be multi functional:

Phenyltrichlorosilane

The trichloro part of the molecule undergoes hydrolysis and condensation and forms a silicon oxide matrix. The phenyl moiety is highly stable and also provides physical flexibility and elasticity in the resulting material. This component increases the CTE from silicon dioxide values.

Vinyltrichlorosilane

This is used to create photosensitivity in the material. A vinyl moiety forms the photosensitivity through the carbon to carbon double bond breakage and continual crosslinking polymerisation. The organic polymer matrix formed increases the CTE. The organic matrix is not as stable as an inorganic silicon oxide matrix. The trichloro part undergoes hydrolysis and condensation and forms a silicon oxide matrix.

Germanium chloride

This is a tetravalent molecule containing four chloride substituents that undergo hydrolysis and condensation to form [Ge-O-Ge] bonds and to form [Si-O-Ge] bonds. This molecule increases the crosslinking density of the material during the condensation polymerization. It increases the refractive index value of the material. The oxide matrix which is formed decreases the CTE of the material.

The material of the lower cladding layer 145 is spun onto a silicon wafer at 1500 rpm and the film is annealed at 230 degC for 4 hours in a nitrogen atmosphere. The material of the core layer 140 is spun onto the lower cladding layer 145 again at 1500 rpm. The film is first baked at 150 degC for 5 minutes, exposed to UV light (365 nm) through a dark field waveguide mask for 30 seconds and then baked again at 150 degC for 10 seconds. The substrate with the film is soaked into a chemical developer to remove unexposed regions of the waveguide core film. The fabricated structures are co-annealed at 235 degC (in nitrogen) for 4 hours. The waveguide core is then exposed to a DUV laser (193 nm) through a phase mask to generate changes in refractive index to create a grating 520 in the waveguide core. Finally, a cladding material 410 is deposited on top of the buffer and waveguide core layers 430, 415 at 1000 rpm and the resulting fully planarized stack is co-annealed at 230 degC for 4 hours. The resulting thickness (height) of the cladding layer is 22454 nm and the thickness (height) and width of the waveguide core layer are approximately 6550 nm. Before integration the waveguide chip with the grating is diced out of the substrate and its optical facets are polished.

A commercial semiconductor laser diode 130 (emitting at 1550 nm range) is “top coated” so that the axis of the optical confinement region 300 of the diode is spaced 25729 micrometers away from the top surface. For example a dielectric or conductive material or a combination of both can be added to the laser diode by chemical vapour deposition, ion-beam evaporation, e-beam evaporation or liquid phase deposition. The diode’s two electrical contacts 505a, 510 are manufactured to be in the bottom of the device and connected at one sidewall respectively.

A suitable material for top coating the laser diode 130 is the hybrid glass material described above as a cladding material 145, 410 for the waveguide 135. This can be spun on while the laser diode 130 is still on a wafer prior to dicing, during manufacture.

The waveguide component 135 is flip-chipped onto bonding material so that the exposed cladding layer 105 abuts the shared substrate 110 and laterally aligned based on standard alignment marks. The chip 135 is pre-bonded to the shared substrate 110 with zero-shrinking epoxy adhesive. The laser diode 130 is flip-chip bonded in similar manner. After that the diode and the waveguide chips 130, 135 are wire-bonded from conductive pads on the chips 130, 135 and on the shared substrate 110. Finally, the chips 130, 135 are partially sealed with non-shrinking epoxy adhesive.

Alternatively the chips 130, 135 can be bonded to the shared substrate 110 using a so called ionic wafer bonding technique or molecular wafer bonding technique, based on for example a coating 10 to 100 nm thick of ethyl trichlorodisilane produced bonding material.

It is sometimes the case that an optical device or component has a non-planar surface. For example, the ridge waveguide 135 described above may offer a non-planar surface. Rough or non-planar surfaces can be complicated to bond and the resulting bond strength can be low due to a small bonding area. Options for dealing with this are for example mechanical or chemical polishing and/or planarisation. Planarisation can be done by spinning an additional thick layer of a material such as a hybrid glass, or an adhesion material, onto the non-uniform surface.

CLAIMS

1. A method of mounting at least two optical components in optical alignment on a shared substrate, the method comprising the steps of:

i) using a planar fabrication technique to adjust the distance between an optical confinement region and a bonding surface in at least one of the optical components so that said distance is matched for optical alignment in use of the at least two optical components; and

ii) flip chip mounting said at least one of the optical components in said optical alignment on the shared substrate by means of its bonding surface.

2. A method according to Claim 1 wherein at least one of the at least two optical components comprises a laser diode.

3. A method according to either one of Claims 1 or 2 wherein at least one of the at least two optical components comprises a planar waveguide.

4. An optical assembly comprising:

i) at least first and second optical components, each having a bonding surface and an optical confinement region; and

ii) a shared substrate,

the first and second components being mounted on the shared substrate by means of their bonding surfaces such that their respective optical confinement regions are optically coupled in use,

wherein the distance from the bonding surface to the optical confinement region for the first component is matched to the distance from the bonding surface to the optical confinement region for the second component to achieve said optical coupling in use.

5. An optical assembly according to Claim 4 wherein the distance from the bonding surface to the optical confinement region for the first component is matched to the distance from the bonding surface to the optical confinement region for the second component to an accuracy of 300 nm or less.

6. An optical assembly according to Claim 4 wherein the distance from the bonding surface to the optical confinement region for the first component is matched to the distance from the bonding surface to the optical confinement region for the second component to an accuracy of 100 nm or less.

7. An optical assembly according to any one of Claims 4 to 6 wherein at least one of the first and second optical components includes a layer of material between its bonding surface and its optical confinement region which layer comprises a glass material having both organic and inorganic components.

8. An optical assembly according to Claim 7 wherein the layer provides the whole distance between the bonding surface and the optical confinement region.

9. An optical assembly according to Claim 7 wherein the layer provides only part of the distance between the bonding surface and the optical confinement region.

10. An optical assembly comprising at least first and second optical components mounted in optical alignment with each other, each component comprising at least one layer and a substrate and providing an optical confinement region in use, wherein the optical assembly further comprises a shared substrate, the first and second optical components each being mounted so that its optical confinement region lies between its respective substrate and the shared substrate.

11. An optical assembly according to Claim 10 wherein the substrate comprised by the first component has different characteristics from the substrate comprised by the second component.

12. An optical assembly according to Claim 11 wherein the substrate comprised by the first component has a different depth from the substrate comprised by the second component.

13. An optical assembly according to any one of Claims 4 to 12 wherein at least one of the first and second optical components comprises a laser diode.

14. An optical assembly according to any one of Claims 4 to 13 wherein at least one of the first and second components is provided with an electrical connection by means of its bonding surface.

ABSTRACT

Optical devices are flip chip mounted onto a substrate for improved alignment. Each device is fabricated using "build-up" layers above a substrate. Each has an optical confinement region in which optical radiation travels in use, and a bonding surface. The depth of the layers above the optical confinement region is closely controlled during fabrication so that when the devices are subsequently flip chip mounted adjacent one another on a shared substrate by means of their bonding surfaces, they can be passively positioned so that their optical confinement regions abut and optical radiation can be coupled from one to the next in use.

(Figure 6.)

FIGURE 1

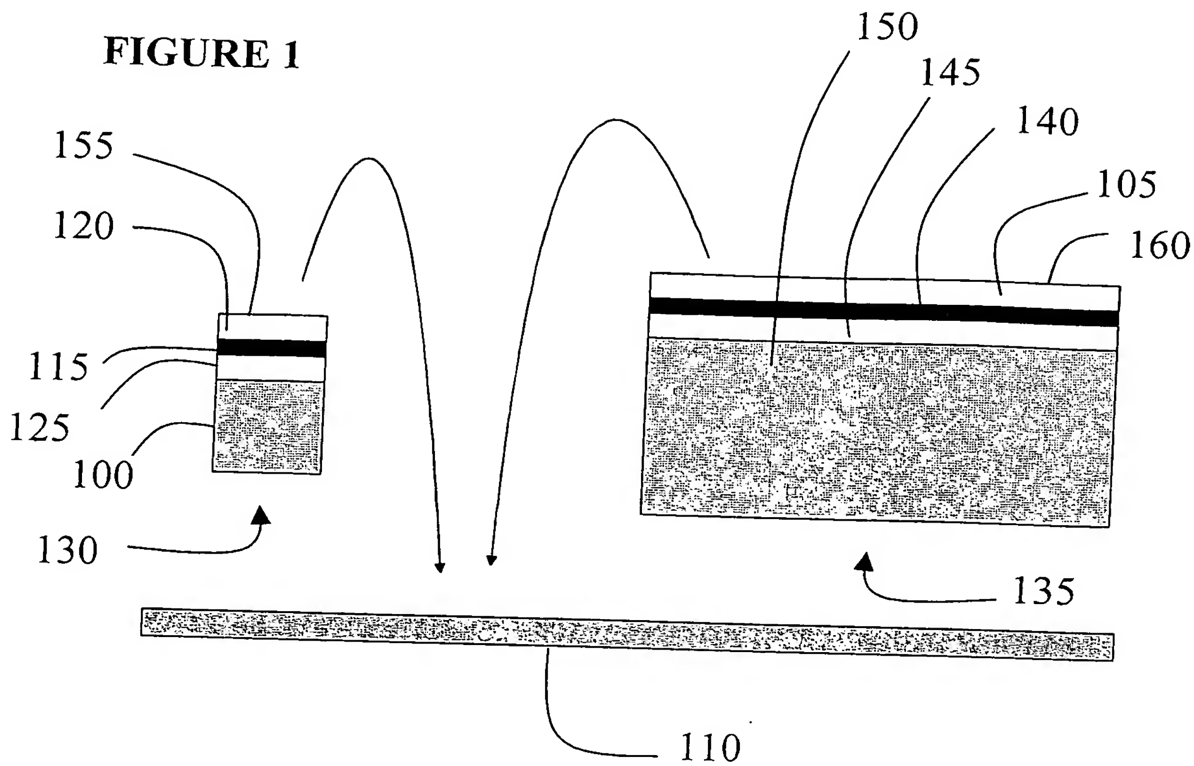
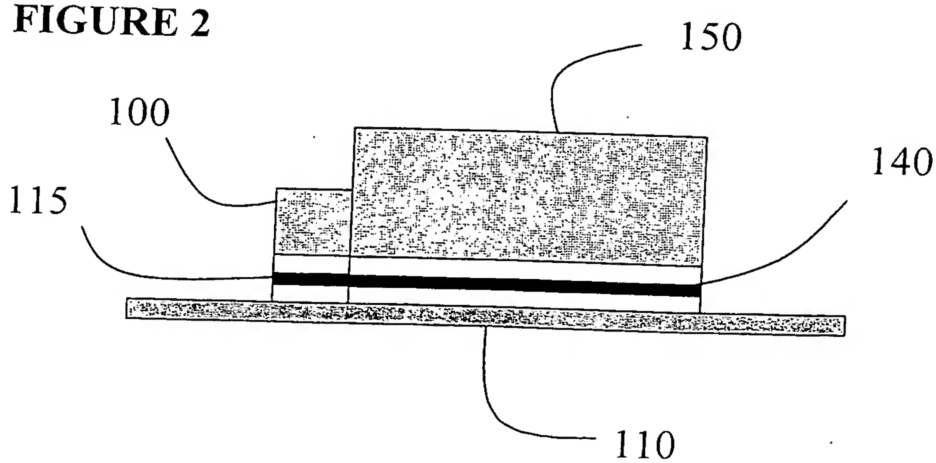


FIGURE 2



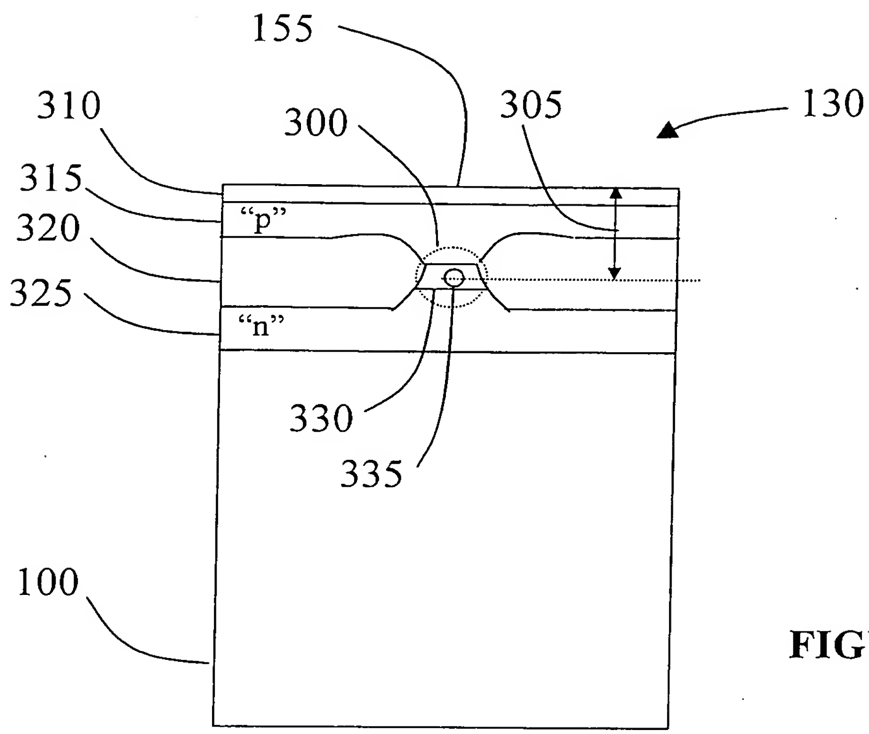


FIGURE 3

FIGURE 4

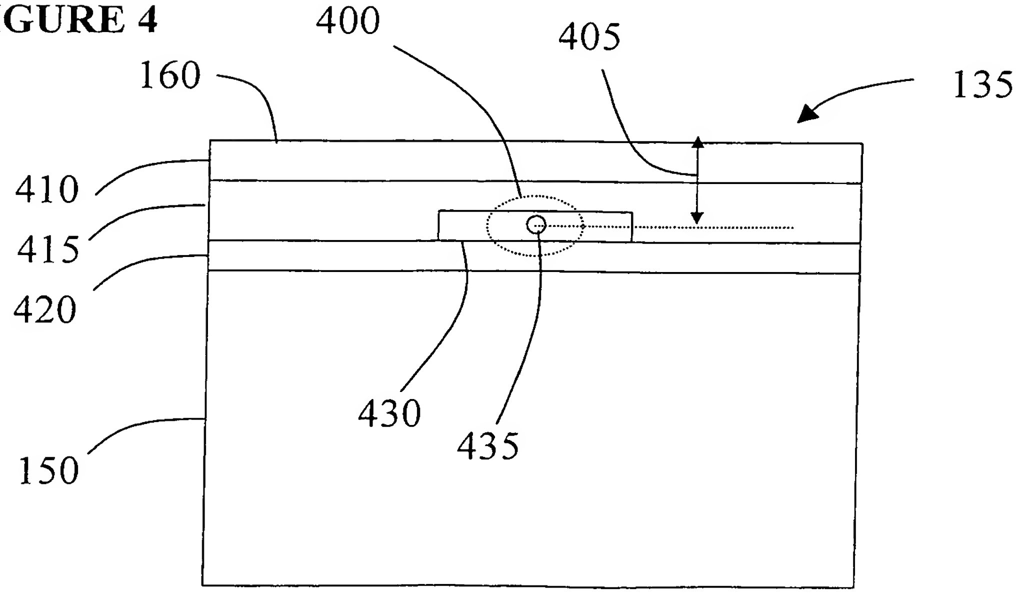


FIGURE 5

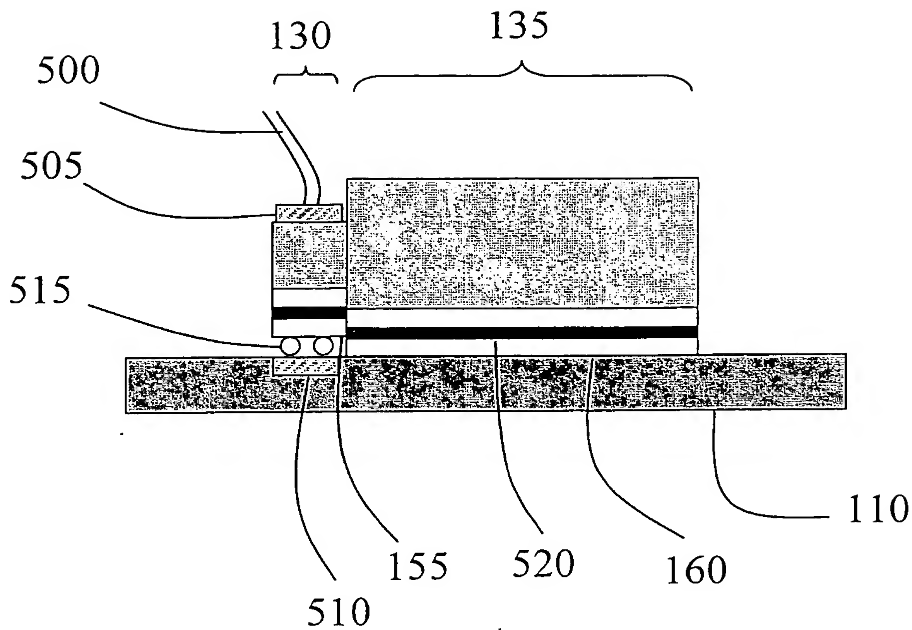


FIGURE 6

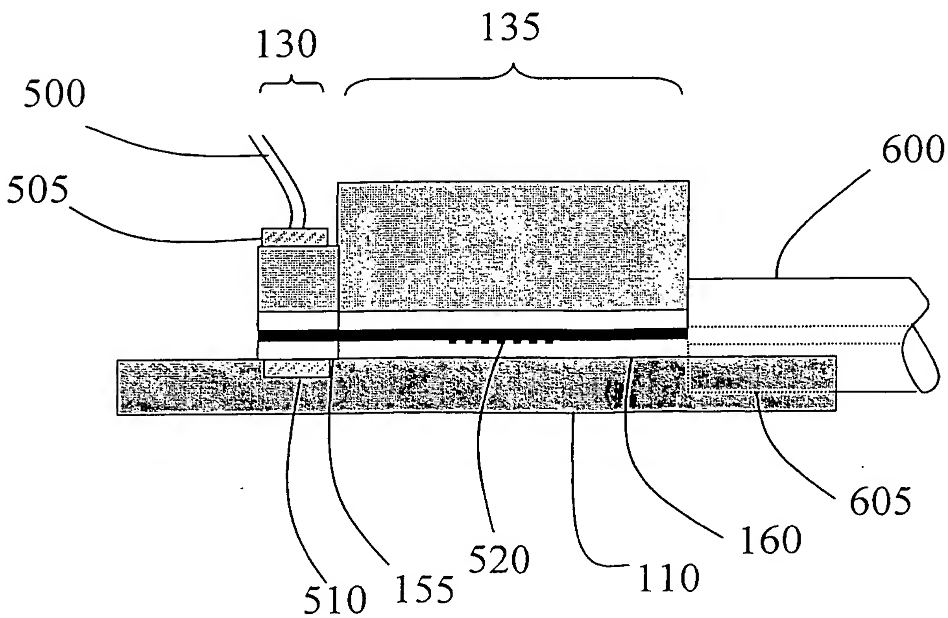


FIGURE 7